The integration of muscle perforator flaps into a community-based private practice.

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The Integration of Muscle Perforator Flaps into a Community-Based Private Practice

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KEYWORDS

• Muscle perforator flap • Private practice • Microsurgery

In early 1984, Song and colleagues[1] showed how a large, undelayed fasciocutaneous flap could be reliably raised from the anterolateral thigh based on a septocutaneous perforator from the descending branch of the lateral circumflex femoral vessels. The author's senior partner at the time coincidentally was referred a patient who had degloved his ankle and heel pad in a motorcycle accident, with exposure of the Achilles tendon and multiple open fractures of the hindfoot (**Fig. 1**). Because of the extremely large size of the defect, he suggested that, although a novel idea, this thigh flap would be a terrific solution if used as a microsurgical transfer. The requisite huge flap was designed and raised following all of the instructions carefully; and predictably—in retrospect—no septocutaneous perforator could be found, but instead after dissection of the entire anterior thigh there was only a single, and what was considered a relatively tiny, musculocutaneous perforator of the vastus lateralis muscle. With no guidelines to follow, instead of abandoning this donor site, it seemed plausible to tediously dissect the perforator through the muscle, with careful coagulation of all muscular side branches, back to a reasonably large caliber source vessel. Despite the trepidation in doing this, the flap survived completely without further sequelae (see **Fig. 1**).

After gleaning through the original Song and colleagues[1] article now numerous times since, a fine print disclaimer is noted that states that occasionally the perforator to what is still today called the anterolateral thigh flap may pass "through a thin layer of muscle fibers before entering the skin."[1] The author's group had actually harvested a muscle perforator free flap without knowing it, because this appellation did not exist at that time. Compared with the more conventional muscle free flap donor sites in use then, this dissection had been so difficult and the stress of performing just a microvascular anastomosis was so great because the authors had just begun that learning curve that they vowed never to use this flap again. Little did they know what the future would bring.

Disregarding the preceding historical footnote, the role of fasciocutaneous flaps as a soft tissue alternative or supplement to muscle flaps, which were popular at that time, became obvious and otherwise intriguing.[2] A relatively obscure treatise in 1986 by Nakajima and colleagues[3] suggested that the deep fascia has 6 different types of perforators, and that each could potentially nourish a skin flap (**Fig. 2**). Although one of these, the *perforating cutaneous branch of muscular vessel*,[3] traversed the muscle, its intended course was primarily directly to the integument. They

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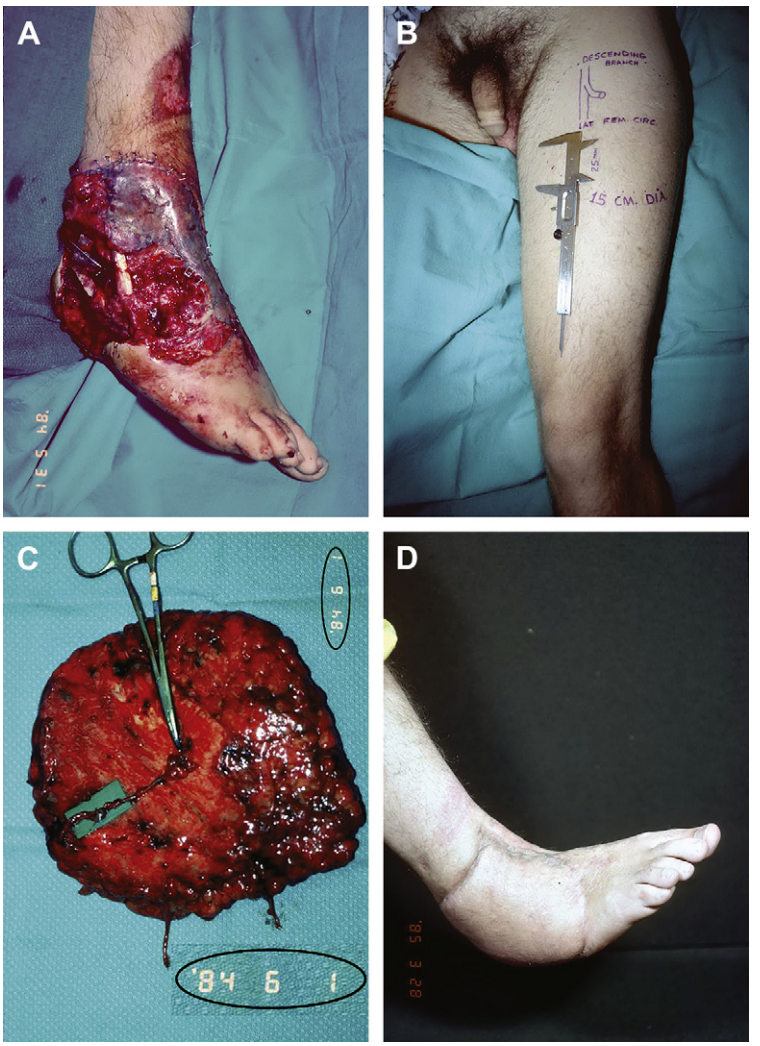

Fig. 1. (*A*) Degloving injury of left hindfoot. (*B*) Proposed design of thigh flap based on septocutaneous perforator presumed to be found at the junction of the middle and upper thirds of the thigh according to the instructions of Song and colleagues.[1] (*C*) Undersurface of free anterolateral thigh flap with what proved to be a musculocutaneous perforator (on microgrid) entering its center; note encircled date of event that is magnified in inset below. (*D*) Well-healed muscle perforator flap 1 year later that salvaged foot.

postulated that this perforator could stand alone to serve a "perforating cutaneous branch of muscular vessel flap."[3] Because this type of flap will always require the tedious intramuscular dissection of that musculocutaneous perforator, Wei and colleagues[4] defined these as "true" muscle perforator flaps.

The author's personal reindoctrination into this concept of muscle perforator flaps awaited his response to a flyer advertising the 5th International Course on Perforator Flaps in Gent, Belgium in 2001, at which Steve Morris had also matriculated to be an observer. As overseen by the course chairman, Philip Blondeel, the attributes of muscle perforator flaps became more apparent, including their large potential size, large-caliber vessels with long vascular pedicles, and abundance of donor sites to better match the characteristics of any possible recipient site. In an attempt to be intimately involved in this nascent field, the author presented an abstract reviewing anatomic dissections of gastrocnemius musculocutaneous perforators[5] just before a clinical series by Cavadas and colleagues,[6] which is now known as the *sural artery perforator flap* according to the Canadian nomenclature terminology.[7] One of the panelists, Fu Chan Wei, in response to the author's question, actually entered the audience to debate just what were "perforator flaps." This discussion led to the idea that perforators could be "direct" or

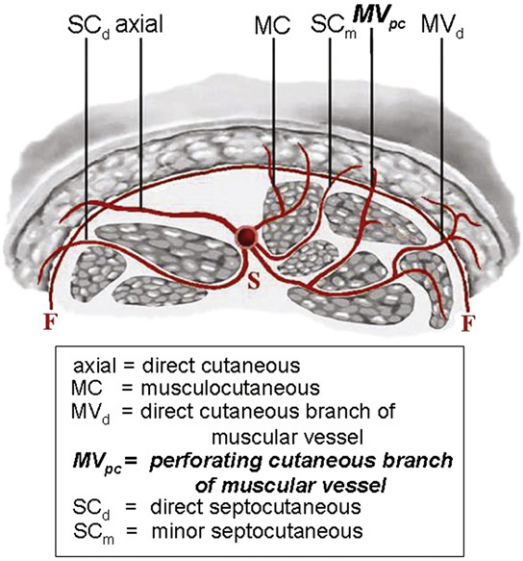

Fig. 2. Six different forms of perforators potentially pierce the deep fascia before proceeding to the integument, as listed.[3] Their "perforating cutaneous branch of muscular vessel" first traverses the given muscle with its destination primarily to be the overlying skin, to serve as the vascular pedicle of what today would be considered a "true" muscle perforator flap.[4] F, deep fascia; S, source vessel.

"indirect," with muscle perforator flaps the quintessential representative of the latter[8] and enduring as the primary topic of that course, and for the remainder of this compendium, for the sake of clarity.

METHOD AND MATERIALS

The author's private practice in a community setting started after completion of typical University training in 1982. Random flaps were still in vogue, and therefore this opportunity permitted the introduction of the relatively new concept of muscle flaps, followed soon after by various forms of fasciocutaneous flaps, both proving to be a better technique for soft tissue reconstruction (**Table 1**). Although readily transferred as local or pedicled flaps, the existing vacuum of other plausible alternatives allowed investigators to hone their microsurgical skills and enabled the simultaneous introduction of microvascular tissue transfers, or free flaps (see **Table 1**). From an awkward beginning, and thereafter often following a rocky road virtually without knowledgeable supervision, muscle perforator flaps were eventually reintegrated in 2001 (see **Table 1; Table 2**) into what has primarily been a solo practice within this same community from 1982 to now.

RESULTS

In the early 1980s, when a soft tissue reconstruction was considered by the author's group, muscle flaps were the predominant selection (see **Table 1**). By the 1990s, fasciocutaneous flaps had assumed an almost equivalent role, especially as a local flap option. Beginning in 2002, following the course in Gent, Belgium, muscle perforator flaps gradually assumed a role, primarily as a source of free tissue

Table 1
Timeline of the diversity of soft tissue flaps options used in the community setting[a]

	Muscle		Fasciocutaneous			
			Perforator		Nonperforator	
Year	Local Flap	Free Flap	Local Flap	Free Flap	Local Flap	Free Flap
1982–1986[b]	18	6			7	4
1987–1991[b]	13	8			21	5
1992–1996[b]	18	10			14	5
1997–2001[b]	32	18			13	4
2002	27	25	11	19	14	5
2003	34	30	5	6	14	4
2004	29	21	8	21	13	7
2005	38	16	8	29	13	3
2006	18	5	10	28	19	6
2007	18	10	11	27	16	4
2008	21	20	7	39	18	6

[a] From 1982 to 2008.
[b] Annual mean.

Table 2
Hierarchy of muscle perforator flap donor sites used in the community setting[a]

	Local Flap	Free Flap	Total
Anterolateral thigh	7	108	115
DIEP	3	29	32
SAP	16	15	31
MCFAP	7	19	26
GAP	13	1	14
All others	20	10	30
	66	182	248

Abbreviations: DIEP, deep inferior epigastric perforator; GAP, gluteal artery perforator; MCFAP, medial circumflex femoral artery perforator; SAP, sural artery perforator.
[a] From 1984–2009 to date.

transfers. Although the frequency of muscle flap use has since diminished, the absolute number has remained relatively constant, reflecting the significant growth in the annual number of total flaps used as this practice matured, and the fact that use of muscle as a flap, despite prejudices otherwise, still has a viable role.[9]

The use of microsurgical tissue transfers has also increased dramatically in the past 5 years, and this seems to be the author's unadvertised niche in the Northeastern Pennsylvania region, with muscle perforator flaps far outperforming the numbers of muscle and other fasciocutaneous flaps combined (see **Table 1**).

Although many consider the "big four"[10] of muscle perforator flaps to be the anterolateral thigh flap (ALT), deep inferior epigastric perforator flap (DIEP), superior gluteal artery perforator flap (SGAP), and thoracodorsal artery perforator flap (TAP), the sural (SAP) and medial circumflex femoral artery perforator (MCFAP) flaps were more often selected by the author's group than the SGAP and TAP (see **Table 2**). The ALT flap certainly has been the most versatile donor site, providing large flaps with a relatively consistent anatomy and allowing a long pedicle of large caliber to reach recipient vessels outside the zone of injury with often "macrosurgical" anastomoses,[11] proving to be an ideal soft tissue flap.[12]

The DIEP flap has been the major source for autogenous tissue breast reconstruction in the author's practice, with this choice often being sought by patients who want to minimize any donor site morbidity.[13] In this group's experience, the MCFAP flap has been an excellent free tissue donor site in thinner individuals, whenever the ability to hide the donor site scar is of paramount importance.[14] Also known as the *medial groin flap*,[15,16] the resulting scar is easily hidden completely by clothing. The SAP flaps are the source of a relatively thin cutaneous free flap, even in the most obese individual, that can be harvested with the patient in a supine or prone position.[17] Its greatest attribute has been its use as a local flap for knee coverage,[18] preserving gastrocnemius muscle function or holding it in reserve for later use.[19]

DISCUSSION

The evolution of the flap selection process in this community private practice, as used to solve the usual gamut of reconstructive challenges, has recapitulated the timeline of the general plastic surgery community. In the early 1980s, muscle flaps predominated as the preferred soft tissue flap, until Pontén's[20] "superflaps" reintroduced what would become the concept of a fascial plexus and the basis of fasciocutaneous flaps. Nakajima and colleagues[3] then theorized a subtype of fasciocutaneous flaps that would become the muscle perforator flap. Kroll and Rosenfield[21] introduced this as a clinical entity, but Koshima and Soeda[22] really deserve the credit for establishing this variant as an important alternative.

As long as a reasonable perforator can be found, a muscle perforator flap can be designed anywhere in the body, either as a local flap to bring similar characteristics in kind to an adjacent defect, or for identical reasons as a free flap to best match a recipient site elsewhere (see **Table 1**). It is ironic that the anterolateral thigh flap, so awkwardly first encountered in the author's initial experience (see **Fig. 1**), continues worldwide to be the most common donor site for a muscle perforator flap.[12] Its large size, reasonable anatomic consistency,[23] large caliber and long vascular leash, and possibility for numerous

chimeric combinations[24] makes this the gold standard of muscle perforator flaps.

As is true for any new facet of life, there is a learning curve.[25] The same microsurgical skills essential for the successful transfer of a free flap will enable an almost innate, meticulous performance of the sometimes demanding dissection of diminutive musculocutaneous perforators; and possession of those skills will make this curve shorter. The author's group has been most fortunate that they have a microscope in their inner-city community hospital to facilitate this dissection whenever necessary. However, no particular new equipment is necessary, just the reasonable and steady hands of a dedicated surgeon willing to innovate a little. Because the author's facility is not as busy as its suburban hospital counterparts, more operative theater time has been allotted to clinicians in the practice to allow the requisite dissection of muscle perforator flaps in relative anonymity, which is important because these take a little longer than traditional flaps.

The limited resources of a community hospital require the author's group to anticipate some common pitfalls and concerns with muscle perforator flaps to minimize risks and complications. Anatomic anomalies are so common that these should be expected, in contradistinction to what the group thought was a misadventure during their original experience in 1984, described earlier. The advent of CT and MRI can facilitate the preoperative identification of requisite perforators[26–28] and may eventually eliminate any exploratory guesswork, but these tests are expensive and not without risk, and therefore the author's group still relies on the traditional acoustic Doppler ultrasound despite its shortcomings, because it is readily available even in the poorest hospital.[29]

Despite sophisticated three- and four-dimensional perfusion studies intended to document the anatomic and perhaps dynamic territory of a given perforator,[30,31] an uncertainty persists because of the great variability among individuals. Therefore, whenever possible to theoretically enhance flap perfusion, the author's group preserves dual perforators that are preferably at opposite extremes of the chosen flap (**Fig. 3**). Another advantage of this configuration is that it will be virtually impossible to accidentally twist and compromise the vascular pedicle, and it also serves as an added safety factor in case of inadvertent injury to one perforator that would otherwise condemn the flap to certain failure. Unfortunately, sometimes this results in a vascular pedicle that is exceedingly long (yet sometimes also an attribute of muscle perforator flaps), and could be subject to kinking unless the surgeon is very careful (see **Fig. 3**).

Venous congestion is another potential problem associated with muscle perforator flaps, because venous outflow does not always follow the same course as the arterial inflow.[32] Again, whenever possible, a subcutaneous vein is preserved as an alternative outflow tract to allow later venous supercharging if indicated. This technique is a recognized solution for the DIEP flap, with retention of a sizeable superficial inferior epigastric vein, if encountered, considered mandatory (**Fig. 4**).[33]

Another frequent cause of venous congestion is excessive pressure on the low-pressure venous

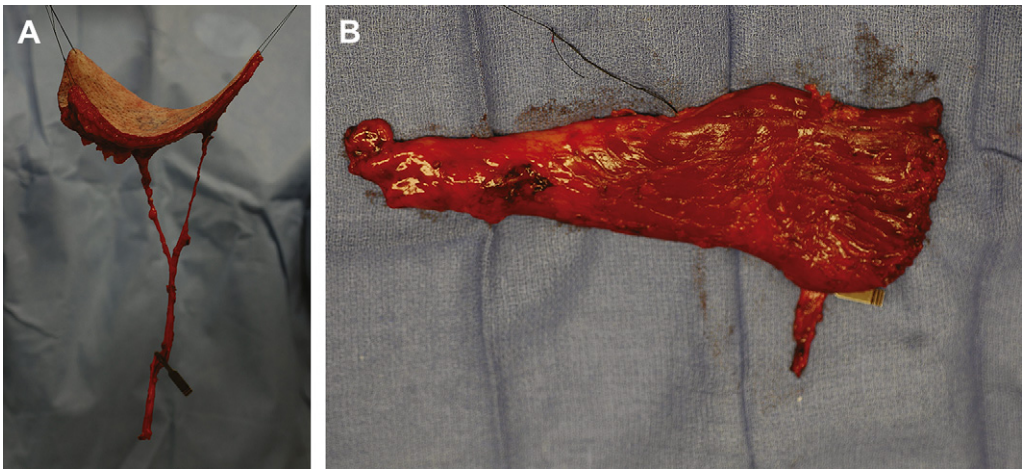

Fig. 3. (*A*) Dual perforators arising from the same source vessel in this anterolateral thigh free flap were both retained because they were similar in size and reasonably separated from each other to theoretically more reliably capture a greater territory. Note the extremely long vascular leash that is possible (*B*), especially when compared with that of the gracilis muscle, which has a notoriously short pedicle.

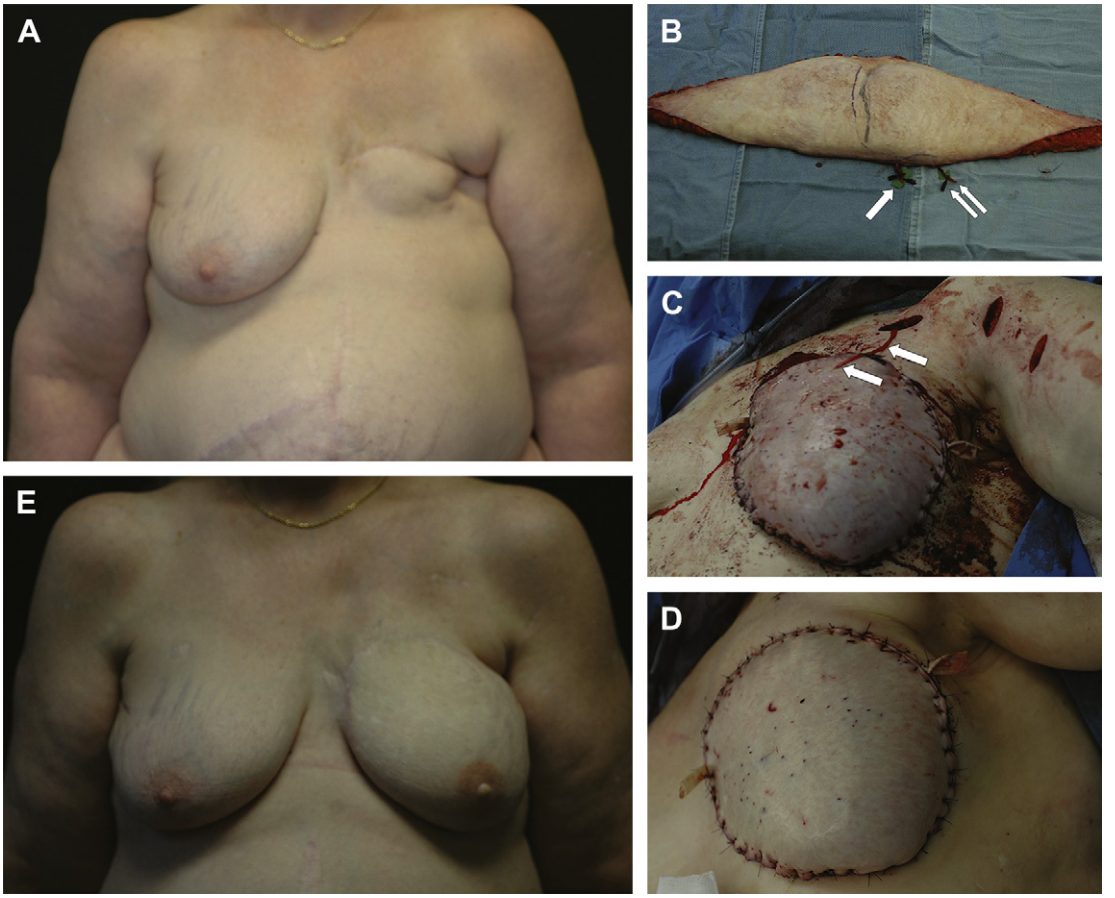

Fig. 4. (*A*) Preoperative candidate who desired autogenous tissues for left breast reconstruction. (*B*) Harvested deep inferior epigastric perforator flap showing the major deep inferior epigastric pedicle (*arrow*), and lateral to it the retained superficial inferior epigastric vein (SIEV; *double arrow*). (*C*) The internal mammary vessels served as the recipient site, but venous congestion ensued. The left cephalic vein (*arrows*) was harvested from the arm through small incisions and coupled to the SIEV to supercharge venous outflow from the flap, with immediate resolution of congestion (*D*), and a reasonable result after nipple creation and areolar micropigmentation (*E*).

side after the ''perfect'' inset, which may not manifest until after the usual postoperative flap edema occurs. This event can be avoided altogether by leaving the subcutaneous tissues on one boundary of the flap untethered and exposed (**Fig. 5**); eventually this side will close spontaneously through the natural process of wound contraction.

SUMMARY

The integration of muscle perforator flaps into the author's reconstructive practice has been a natural and positive experience, allowing greater diversity in flap selection to be offered to the patient population. The problems are no different in patients who present to a community hospital. The author has had the good fortune to be a recipient of Philip Blondeel's zeal in spreading the ''gospel'' of perforator flaps, and the intellectual stimulus of

Fig. 5. The tension created after the "perfect" inset, especially when closing a thick muscle perforator flap, can potentially impede venous outflow. This event can be minimized by closing only the deeper subcutaneous tissue layer of the flap to the defect (*arrow*) to avoid excessive pressure.

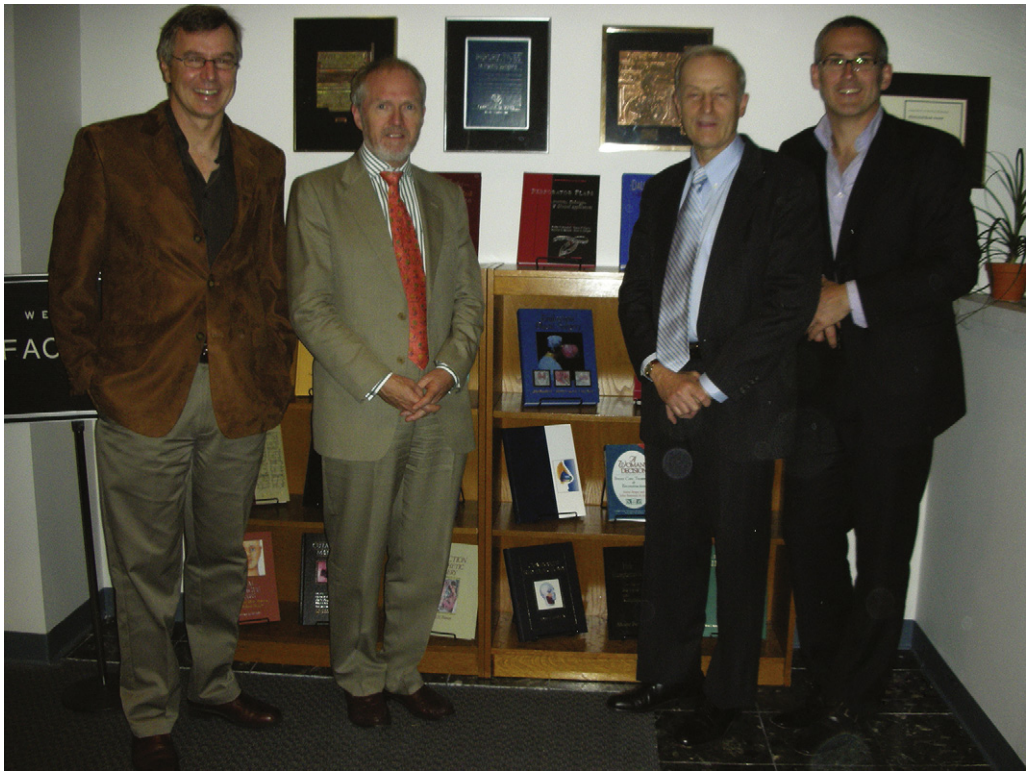

Fig. 6. The "Perforator Gang of Four"—Steve Morris, Peter Neligan, Geoff Hallock, and Phillip Blondeel, (*left* to *right*)—networking in the library.

continuing debates over small details such as nomenclature. The author's colleagues Steve Morris and Peter Neligan have tried to solve this dilemma with their Canadian system.[7] This collaboration has improved global communication and the disbursement of constant improvements in this dynamic field wherever needed (**Fig. 6**), whether now virtually instantaneously through the Internet or still with the written word.[34] Supermicrosurgery, as spearheaded by Koshima and colleagues,[35] may someday allow futuristic "capillary" perforator flaps even to be a mainstay of the community hospital. Time will tell the pathway the field will follow.

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REFERENCES

1. Song TG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. Br J Plast Surg 1984;37:149–59.
2. Hallock GG. Fasciocutaneous flaps. Cambridge (MA): Blackwell Scientific Publications; 1992.
3. Nakajima H, Fujino T, Adachi S. A new concept of vascular supply to the skin and classification of skin flaps according to their vascularization. Ann Plast Surg 1986;16:1–17.
4. Wei FC, Jain V, Suominen S, et al. Confusion among perforator flaps: what is a true perforator flap? Plast Reconstr Surg 2001;107:874–6.
5. Hallock GG. Anatomic basis of the gastrocnemius perforator-based flap. Ann Plast Surg 2001;47:517–22.
6. Cavadas PC, Sanz-Gimenez-Rico JR, Gutierrez-de la Camara A, et al. The medial sural artery perforator free flap. Plast Reconstr Surg 2001;108:1609–15.
7. Geddes CR, Morris SF, Neligan PC. Perforator flaps: evolution, classification, and applications. Ann Plast Surg 2003;50:90–9.

8. Hallock GG. Direct and indirect perforator flaps: the history and the controversy. Plast Reconstr Surg 2003;111:855–66.
9. Hallock GG. In an era of perforator flaps, are muscle flaps passé? Plast Reconstr Surg 2009; 123:1357–63.
10. Hallock GG. A primer of schematics to facilitate the design of the preferred muscle perforator flaps. Plast Reconstr Surg 2009;123:1107–15.
11. Hallock GG. Macrovascular surgery and the microsurgeon. J Reconstr Microsurg 1997;13:563–9.
12. Wei FC, Jain V, Celik N, et al. Have we found an ideal soft-tissue flap? an experience with 672 anterolateral thigh flaps. Plast Reconstr Surg 2002;109:2219–26.
13. Blondell PN, Vanderstraeten GG, Monstrey SJ, et al. The donor site morbidity of free DIEP flaps and free TRAM flaps for breast reconstruction. Br J Plast Surg 1997;50:322–30.
14. Hallock GG. The development of the medial circumflex femoral artery perforator (MCFAP) flap. Sem Plast Surg 2006;20:121–6.
15. Hallock GG. The medial circumflex femoral GRACILIS local perforator flap–a local medial groin perforator flap. Ann Plast Surg 2003;51:460–4.
16. Hallock GG. The gracilis (medial circumflex femoral) perforator flap: a medial groin free flap? Ann Plast Surg 2003;51:623–6.
17. Hallock GG, Sano K. The medial sural medial gastrocnemius perforator free flap: an "ideal" prone position skin flap. Ann Plast Surg 2004;52:184–7.
18. Hallock GG. The medial sural medial gastrocnemius perforator local flap. Ann Plast Surg 2004;53:501–5.
19. Hallock GG. Sequential use of a true perforator flap and its corresponding muscle flap. Ann Plast Surg 2003;51:617–20.
20. Pontén B. The fasciocutaneous flap: its use in soft tissue defects of the lower leg. Br J Plast Surg 1981;34:215–20.
21. Kroll SS, Rosenfield L. Perforator-based flaps for low posterior midline defects. Plast Reconstr Surg 1988; 81:561–6.
22. Koshima I, Soeda S. Inferior epigastric artery skin flaps without rectus abdominis muscle. Br J Plast Surg 1989;42:645–8.
23. Yu P, Youssef A. Efficacy of the handheld Doppler in preoperative identification of the cutaneous perforators in the anterolateral thigh flap. Plast Reconstr Surg 2006;118:928–33.
24. Wei FC, Celik N, Jeng SF. Application of "simplified nomenclature for compound flaps" to the anterolateral thigh flap. Plast Reconstr Surg 2005;115: 1051–5.
25. Hallock GG. Is there a "learning curve" for muscle perforator flaps? Ann Plast Surg 2008;60:146–9.
26. Masiá J, Larrañaga J, Clavero JA, et al. The value of the multidetector row computed tomography for the preoperative planning of deep inferior epigastric artery perforator flap, our experience in 162 cases. Ann Plast Surg 2008;60:29–36.
27. Rozen WM, Phillips TJ, Ashton MW, et al. Preoperative imaging for DIEP perforator flaps: a comparative study of computed tomographic angiography and Doppler ultrasound. Plast Reconstr Surg 2008;121: 9–16.
28. de Weerd L, Weum S, Mercer JB. The value of dynamic infrared thermography (DIRT) in perforator selection and planning of free DIEP flaps. Ann Plast Surg 2009;63:274–9.
29. Hallock GG. Attributes and shortcomings of acoustic Doppler sonography in identifying perforators for flaps from the lower extremity. J Reconstr Microsurg 2009;25:377–82.
30. Saint-Cyr M, Schaverien M, Arbique G, et al. Three- and four-dimensional computed tomographic angiography and venography for the investigation of the vascular anatomy and perfusion of perforator flaps. Plast Reconstr Surg 2008;121:772–80.
31. Schaverien M, Saint-Cyr M, Arbique G, et al. Three- and four-dimensional computed topographic angiography and venography of the anterolateral thigh perforator flap. Plast Reconstr Surg 2008;121: 1685–96.
32. Schaverien M, Saint-Cyr M, Arbique G, et al. Anatomies of the deep inferior epigastric perforator and superficial inferior epigastric artery flaps. Plast Reconstr Surg 2008;1221:1909–19.
33. Villafane O, Gahankari D, Webster M. Superficial inferior epigastric vein (SIEV): lifeboat for DIEP/ TRAM flaps [letter]. Br J Plast Surg 1999;52:599.
34. Blondeel PN, Morris SF, Hallock GG, et al. Perforator flaps: anatomy, technique, clinical applications. St. Louis (MO): Quality Medical Publishing; 2006.
35. Koshima I, Nanba Y, Takahasi Y, et al. Future of supramicrosurgery as it relates to breast reconstruction: free paraumbilical perforator adiposal flap. Sem Plast Surg 2002;16:93–9.